Secondary Management of Mandible Fractures

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Abstract
Mandibular fractures are the most common facial fractures that need surgical intervention. If untreated, these fractures affect a patient’s occlusion, degree of mouth opening, and facial symmetry, and could cause infection with significant pain. The goal of any surgical intervention is to restore the preinjury occlusion, even if the preinjury occlusion is abnormal. Initial therapies, whether surgical or conservative, are not always successful, however, and revision or delayed surgical intervention can be challenging. Herein, we review common causes of failure of primary surgical management of mandibular fractures and provide tips to successful secondary intervention.

Keywords
► complications
► malocclusion
► revision
► Le Fort osteotomy
► secondary repair

Nonunion and Infection
Nonunion of the mandible is defined by a fracture that fails to heal within a normal period: 4 weeks without treatment or 8 weeks after surgical management.1 This timeframe is derived from the average amount of time for a bony, callous union to form in a healthy individual. Nonunion occurs with a reported incidence of 2.8%,2 most commonly in the body and angle of the mandible, and multiple contributing factors...
in the development of nonunion have been proposed. In Mathog et al’s retrospective review of 906 patients with mandibular nonunions, multiple fractures, failure to provide antibiotics, teeth and tooth roots in the fracture line, alcohol and drug abuse, surgeon inexperience, and a lack of patient compliance all contributed to the development of nonunion. Inadequate stabilization and reduction of the fractured segments have also classically been important contributory factors to nonunion.

Infection is one of the most common complications to occur after a mandibular fracture, and it is often associated with nonunion. Osteomyelitis and infection can cause inflammation and prevent healing, culminating in bony nonunion. Failure to provide antibiotics and a delay in initial treatment are possible contributory factors to infection, though these factors have also been debated in the past.

There is a lack of well-designed prospective studies to reliably determine the importance of treatment delay as an independent predictor of postoperative complications including nonunion. Additionally, because of the possible serious consequences of infection, it has traditionally been routine to administer postoperative antibiotics. However, in recent years, this has also been questioned.

In a systematic review of 31 eligible studies and 5,437 patients, Kyzas found that existing evidence in support of the use of prophylactic postoperative antibiotics is of poor quality. If one were to administer prophylactic preoperative antibiotics, there is still insufficient evidence to outline the optimal dosage, duration of course, and best route of administration. There also are not many studies to extrapolate the number needed to treat with prophylactic antibiotics to prevent one complication. If the decision is made for prophylactic antibiotic, the risks to be considered include medication reactions and the potential for an allergenic reaction. In a recent meta-analysis including seven randomized controlled trials and six cohort studies, Habib et al found that use of prophylactic antibiotic postoperatively is not contraindicated, but, as with any treatment, the unique characteristics of each patient and situation must be thoroughly assessed.

Secondary surgical management of nonunion starts with mitigation of any apparent causes of the nonunion, especially infection. There has been a paradigm shift in the past couple
decades regarding the best secondary management of mandibles with nonunion and infection. Traditionally, a two-stage approach of repair was advocated; the first stage involved controlling the infectious process with removal of involved teeth, drainage of any abscess, and the administration of antibiotics. After demonstration of resolution of the infection, then a secondary surgery could be undertaken with reduction and fixation of the bony segments. In this model, fixation may be delayed several months to allow for infection resolution, as many physicians believed that internal fixation should not be placed in infected bone and tissue, as the plate may prolong the infection or prevent resolution altogether. Thus, splints, external fixators, and maxillofacial fixation were necessary to immobilize the fractured segments, prevent contracture, and promote healing until internal fixation could be undertaken.

It was not until the past couple decades that surgeons hypothesized that the lack of stabilization was one of the main etiologies of infection and nonunion; the movement of the fractured segments could interrupt healing, contribute to inflammation and infection, and lead to nonunion. Both Koury and Ellis, and Mehra et al have since demonstrated success with single-stage management of infected mandible fractures with rigid internal fixation. Furthermore, in a retrospective study of 43 patients, Benson et al successfully used a single-stage repair with immediate autogenous bone grafting to treat infected mandibular fractures when the reduced segments are not in contact with one another. The results of all these studies challenge the historical belief that an infection must be cleared prior to bone grafting.

Advances in rigid internal fixation techniques over the two decades have also allowed for a greater degree of stabilization of fractured segments and a much quicker return of function. However, despite these advances, Mathog et al found that the incidence of nonunion has not decreased but rather found the rate of nonunion to be higher when there were multiple fractures present and to vary by fixation technique (lag screws: 8%; rigid internal fixation plates: < 3%, and champy noncompression miniplates: < 2–24%). This highlights the difficulty of providing stabilization when multiple fractures are involved and the importance of choosing the correct techniques for stabilization. Overall, in the modern age, there are only a handful of situations in which a surgeon may need a two-stage approach to repair nonunion (whether infected or noninfected). One such situation is in the presence of a significant soft tissue deficit.

Treatment of mandibular nonunion involves debridement of nonviable bone, proper reduction of segments, and rigid fixation to achieve stabilization/immobilization of segments. After debridement, one may find poor bony contact of segments; the maximum amount of space between fragments that can be expected to heal is 3 mm. In these situations, nonvascular bone grafts (NVBGs) can be used to bridge the gap between segments. NVBGs can be harvested from the ilium, rib, fibula, calvarium, or even the ramus, and they carry the advantages of shorter operating times, less blood loss, and lower costs than vascular bone grafts (VBGs). However, the use of an NVBG is limited by the size of the defect and sufficient soft tissue coverage. Multiple sources state that the failure of nonvascularized bone grafts is closely correlated to the length of the defect. Pogrel et al compared NVBGs with VBGs and found a success rate of 95% in VBGs and 72% in NVBGs. They found that the failure of the NVBGs was directly related to the length of the defect, noting a failure rate of 17% for grafts < 6 cm in length.

Akinbami systematically reviewed six studies evaluating the success of bone grafts in mandible fractures and identified multiple factors linked to the failure of NVBG, the most prominent of which were use of a nonrigid fixation method (such as trans-osseous wires), infection, and defects > 6 cm in length. Overall, success rate in defects > 6 cm were still considerably high (72–100%) in the presence of favorable conditions such as good vascularity and inherent regenerative capacity, but the review suggested that despite high success rates with favorable conditions, NVBGs should still be avoided when there are gross soft tissue deficits.

Extrapolating from their results, in a situation in which a defect is > 6 cm with a gross soft tissue deficit, the surgeon could either (1) wait for soft tissue healing (two-stage approach), (2) utilize alternative synthetic materials and other techniques to achieve proper soft tissue coverage at the time of mandible repair, or (3) repair the mandible in a single stage with a VBG that includes a skin paddle. VBGs have higher success rates, as they not only provide vascularized soft tissue coverage but can allow faster healing and resistance against infection. VBGs are limited, however, by the surgeon’s expertise, increased costs, and longer operating times. The fibula free flap is the most commonly used VBG, as it provides a large amount of bone, can accommodate dental implants, and can provide a large and highly vascular skin paddle.

Condylar Fractures: Malunion, Malocclusion, and Facial Asymmetry

Condylar and subcondylar fractures make up an estimated 29 to 32% of all mandibular fractures in the United States. Furthermore, it is estimated that 46% of condylar fractures are associated with other mandibular fractures. Due to the unique horseshoe shape of the mandible, one or both condyles are subject to fracture when affected by a force either directly over the condyle or the anterior portion of the mandible. Common causes of condylar fractures include aggravated assault, falls, sports-related injuries, and motor vehicle accidents. Malocclusion resulting from mandibular trauma is most often due to condylar fractures. The incidence of malocclusion development from a condylar fracture is estimated to be 1.4 to 13%. Malocclusion can occur from a lack of treatment (delayed presentation) or unsuccessful treatment. Malunion, malocclusion, and facial asymmetry can be discovered during the healing process or later after edema has subsided. Certain types of malocclusion and asymmetry can be found depending on unilateral versus bilateral condylar fractures. Unilateral condylar fracture could result in shortening of the ipsilateral ramus, thus causing decreased ramus and posterior facial height and contralateral open bite. Bilateral condylar fracture...
could result in decrease of bilateral rami height and, consequently, an anterior open bite.

Ellis and Throckmorton evaluated the differences in posterior facial height of patients treated with open and closed treatment of unilateral condylar fractures and found significantly shorter posterior facial and ramus heights on the side of injury in patients treated with closed treatment. With closed treatment, it is accepted that there will be a degree of malunion of the fractured segments, the expectation being that, with remodeling, a functional neoarticulation that is harmonious with occlusion will still develop.

**Treatment**

The goal of treating malocclusion and malunion, as with all mandible fractures, is to restore the preinjury occlusion, though patient-specific goals, expectations, and tolerance of different methods should also be considered. Depending on the degree of malocclusion, conservative treatment may be all that is necessary. The patient may complain of dental pain upon occlusion, often caused by hyperocclusion, or premature contact of teeth. A combination of orthodontics, prosthetics, and exercises may be employed for the correction of minor malocclusion. It is important that the patient understands that full rehabilitation to the prior state of occlusion is not always possible with just conservative treatment.

If the malocclusion or facial asymmetry caused by a condylar fracture is severe enough or does not resolve with conservative measures, then surgery can be undertaken. There are multiple factors that influence the choice of treatment modality. These factors are listed in Table 1. The time at which a patient presents with malocclusion is important, with early presentation (fewer than 3 months) amenable to rehabilitative physical therapy. This involves forced dilation of the mandible in the presence of hypomobility, repositioning of the mandible into proper occlusion, and promotion of rehabilitative exercises. Patients are encouraged to move the mandible and perform stretching exercises throughout the day. Arch bars are placed so that guiding elastics may be used to maintain proper occlusion when the mouth is closed. In essence, the fracture is treated like a fresh fracture with closed treatment technique, but the treatment is long enough for a stable neoarticulation of the temporomandibular joint (TMJ) to form in the setting of stable occlusion.

If the patient presents after 3 months, the TMJ has already remodeled and undergone fibrous and osseous changes. A stable neoarticulation has likely formed by this point, which would provide the condylar stability required for the correction of malocclusion through orthognathic surgery. Prior to proceeding with surgical planning, the patient must be assessed for temporomandibular disorder and/or myofascial pain and appropriately treated with a combination of splint therapy, physical therapy with range-of-motion exercises, nonsteroidal inflammatory drugs, and muscle relaxants. TMD and hypomobility are addressed prior to orthognathic surgery, as the surgery itself may worsen hypomobility, and the presence of hypomobility may make intraoral surgery more difficult. Additionally, TMJ reconstruction may be considered if symptoms persist.

Orthognathic surgery is a stable and predictable method of correcting malocclusion. The treatment of an anterior open bite, usually caused by bilateral condylar fractures, is largely dependent on symmetry of the malocclusion. If a patient’s mandibular midline, for example, is coincident with the maxillary midline (indicating some degree of mandibular symmetry), then a Le Fort osteotomy may be appropriate. It should be noted that this procedure does not correct rami height discrepancies, but it does avoid manipulation of the condyles, which could cause refracture. It is important to remember that condylar stability plays an important role in the success of orthognathic surgery. In the presence of gross asymmetry of the mandible, including ramus height discrepancies, a sagittal split ramus osteotomy could provide the movements required to correct those abnormalities. A unilateral ramus osteotomy is performed on the fractured side, which can also restore ramus height. Sometimes, a second osteotomy site is required to correct the height abnormalities, as there is improved stability with the use of bilateral osteotomies. If orthognathic surgery is deemed necessary, some sources recommended that the surgery be delayed 6 months to avoid the risk of remobilizing a malunion.

![Fig. 5](image_url)

**Table 1** Factors affecting the surgical treatment of condylar fractures

<table>
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<tr>
<th>Degree of malocclusion</th>
<th>Timing of malocclusion presentation</th>
<th>Presence of TMJ symptoms</th>
<th>Symmetry of the malocclusion</th>
<th>Presence of preexisting severe malocclusion</th>
<th>Ramus fracture pattern</th>
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Abbreviation: TMJ, temporomandibular joint.
Noncondylar Fractures: Malunion, Malocclusion, and Facial Asymmetry

Malocclusion and malunion resulting from noncondylar mandibular fractures can be approached similar to an original repair. First, maxillomandibular fixation (MMF) is placed, and previous hardware is removed. Next, the fractured segments are realigned and refixed in the proper position. MMF is then released to confirm the occlusion. In the late repair of malunions, an osteotomy could be performed at the original fracture site, but sagittal or vertical ramus ostotomies could also be performed (Fig. 4). The former would be elected if realignment at the original fracture site would correct an obvious malocclusion. This is true with fractures in tooth-bearing segments such as the body or symphysis. A prefabricated surgical splint is used to set the planned occlusion, and new rigid fixation is applied.

The surgeon must also be aware of certain fracture patterns that have a tendency of widening of the lower face, as facial widening in these cases is preventable. A classic example of this is a symphyseal fracture, with or without condylar fracture. With fractures of the symphysis, there is a natural propensity for the symphysis to move posteriorly and the rami to flare due to the pull from the suprahyoid, masseter, and temporalis muscles.20 The intraprocedural application of lateral wires for MMF may further contribute to flaring of the rami; lateral forces can cause lingual tilting and rotation. This can occur even when the teeth in the mandibular fragment appear to be interdigitated with the maxillary dentition and proper occlusal arch form is obtained. In these cases, the flaring is best detected at the inferior border of the mandible along the lingual cortex. The presence of a concomitant condylar fracture may cause lateral movement of the rami; as opposed to flaring or rotation, as there is no longer a stable posterior articulation with the skull. A lack of dentition will also complicate matters, as normal interdigitation of teeth provides resistance to the flaring and rotation. Additionally, the maxillary teeth are usually used as a blueprint to aid proper reduction of mandibular fractures.

Double unilateral mandibular fractures are difficult to manage and are associated with facial widening.15 Cillo and Ellis found that double unilateral fractures have an incidence of 2.4% among mandible fractures, and they identified numerous barriers to the successful management of different combinations of fractures.15 First, for a mandible with both body and angle double unilateral fractures, the central segment of bone may only have a couple of teeth for interdigitation with the maxillary dentition. When wires are secured to the lateral side of the dentition for MMF, there can be inadvertent lateral flaring at the gonial angle and inferior border. Next, when there is a fracture of the body and the ipsilateral condyle, there is no stable posterior articulation when closed management is chosen. Therefore, with MMF application, there is similar tendency for flaring of the inferior border and gonial angle. The angle-and-condyle fracture combination is the most difficult combination of fractures to obtain accurate reduction.

Treatment
The surgical principles for prevention and retreatment of these cases are similar and involve a certain degree of vigilance. First of all, the appropriate approach must be taken, which would allow the surgeon view of the inferior border and, thus, the lingual cortex. During MMF, examine the teeth as digital pressure is applied to the angles. This is to check for uprighting of the teeth from a tilted/flared position, and it may require minimal loosening of the wires. Check the inferior border to ensure that there is apposition of the lingual cortex; one must remember that the lingual cortices may not be properly reduced, although the buccal cortices appear to be reduced, teeth are properly interdigitating, and the occlusal arch form looks continuous. An additional method to check for proper apposition of lingual cortices in the symphys is pressing against bilateral rami once the fracture appears reduced. If the lingual cortices are indeed properly reduced, the buccal cortices should start to separate, as the lingual cortices act as a fulcrum. The bone plates should first be accurately bent and then overbent in the area of the fracture. It is common to incorporate this overbend for symphyseal fractures, as, geometrically, even a small separation of the lingual cortex can cause a significant amount of widening at the rami. The purpose of this intentional overbend is to apply a compressive force at the lingual cortex when the plate is applied. In edentulous patients, the patient’s dentures could be used as a guide for reduction; if there are no dentures to use, gunning splints will need to be used.

Conclusion
Secondary correction of mandible fractures is necessary when initial treatment has been unsuccessful in restoring appropriate, premorbid occlusion, and facial symmetry. There are numerous pitfalls which reconstructive surgeons should be aware of, especially when revising condylar fractures, bilateral fractures, and double–unilateral fractures.

Conflicts of Interest
None declared.

References